Leadville, Biomass, and Hydrogen Energy

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Leadville Energy Today

Coal

e^- \$2.40 GGE

Natural Gas

88c GGE

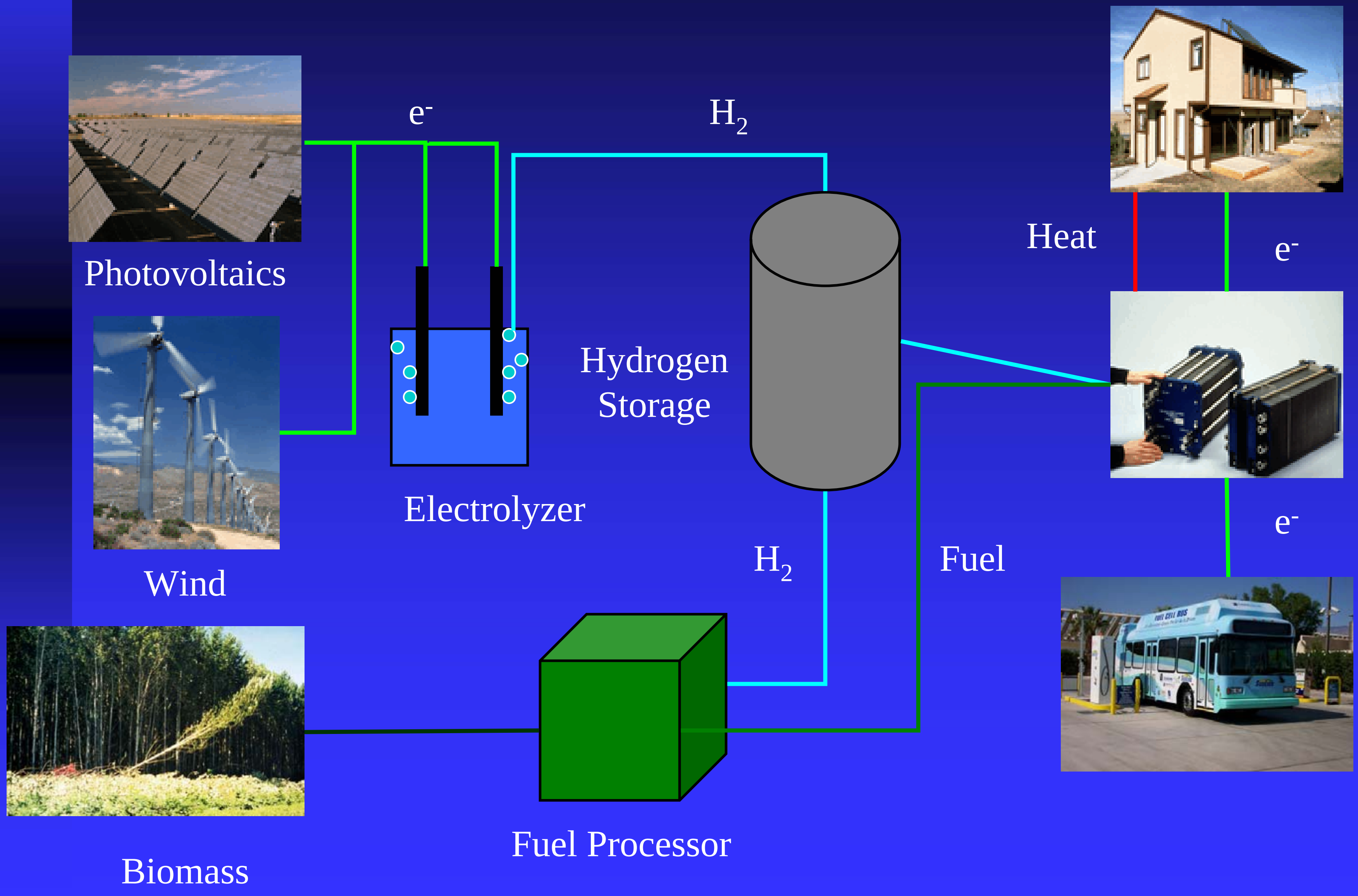
Oil

$1.70 GG

Needs

- Jobs
- Super Fund Clean up
- Forest Fire Mitigation

Renewable Hydrogen Energy



Healthy Forest Initiative

- Federal program to encourage forest thinning in fire prone red-zone
- Most biomass to be removed will be small diameter trees
- Need to develop a market/use for wood chips
- Transportation costs significant for this “waste” biomass stream

Wood Chip Fired CHP

- Wood chips transported to central location
- Used to fire boiler
- Hot water or steam piped through district heating system
- Possibility of using steam to produce electricity in steam micro-turbine

Biomass Gasification

- Partial combustion of biomass with air
- Produces a gas 20 % H_2, 20 % CO, 2 % CH_4, 42 % N_2, 8 % CO_2, 8 % H_2O
- Can be used directly in an engine genset, microturbine or solid oxide fuel cell

Pyrolysis Oil

- Fast pyrolysis – rapidly heat biomass in absence of air to produce oil, gas and char.
  Gas and char combusted to dry wood.
- Wood – 50 % water, Oil – 20 % water and higher calorific value
- “Concentrated biomass” less expensive to transport

In Forest Pyrolysis Reactor

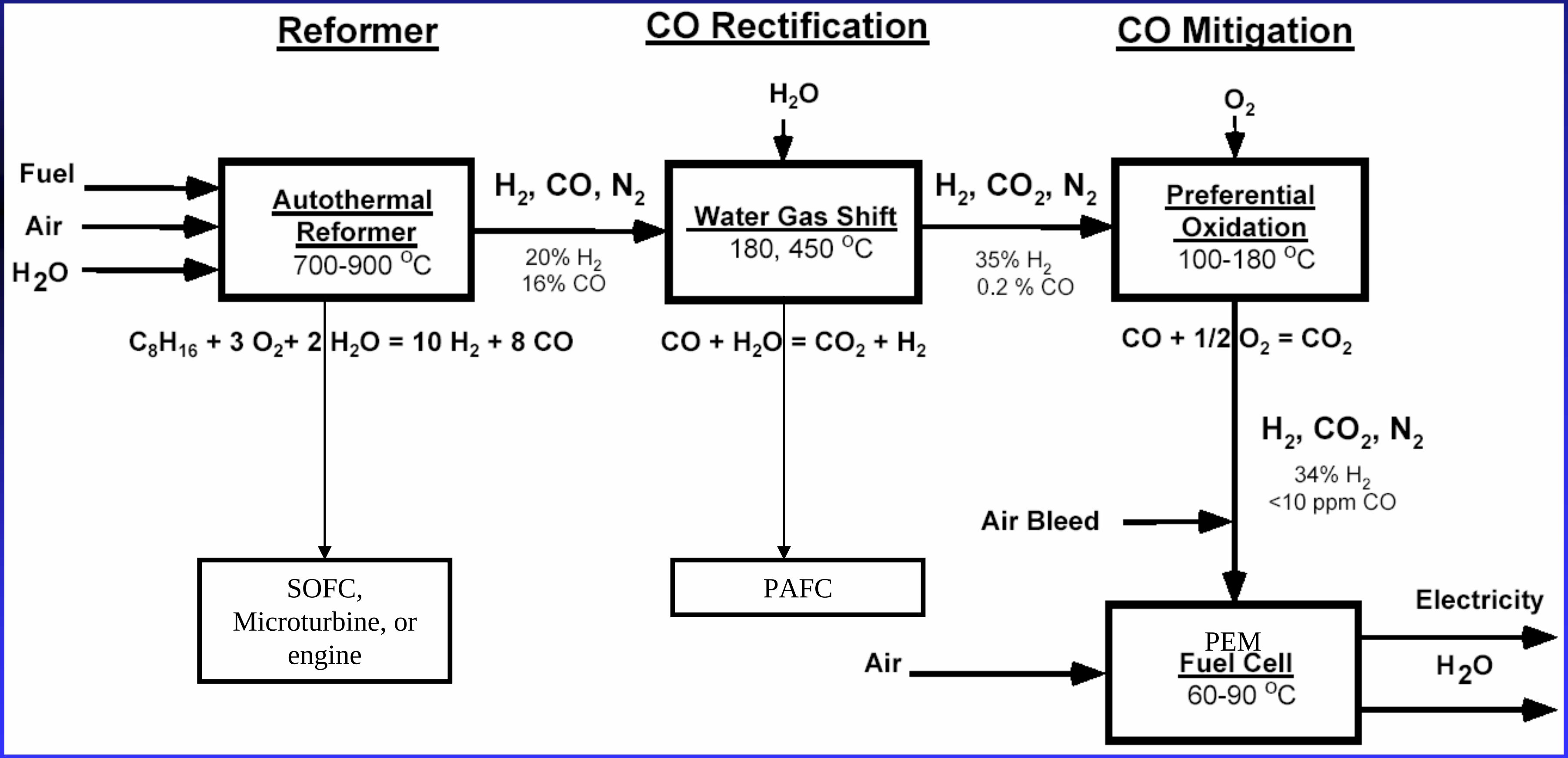
Carbon Products for the Mining Industry

- Carbon absorbents for mitigation of acid mine waste
- High quality carbon for use in gold refining as a cost effective alternative to coconut shell carbon




Reforming

- Depending on the application some fuel processing is necessary



H_2 2010 DOE Cost Targets

- Via Pyrolysis - \$2.90 Kg/H_2
  - Feedstock 70c
  - Pyrolysis \$1.50
  - Reforming 40c
  - Purification 30c
- Via Gasification - \$2.50 Kg/H_2
- Via Natural Gas - \$1.50 Kg/H_2
  - Feedstock 58c
- Via wind/PV electrolysis - \$2.00 Kg/H_2

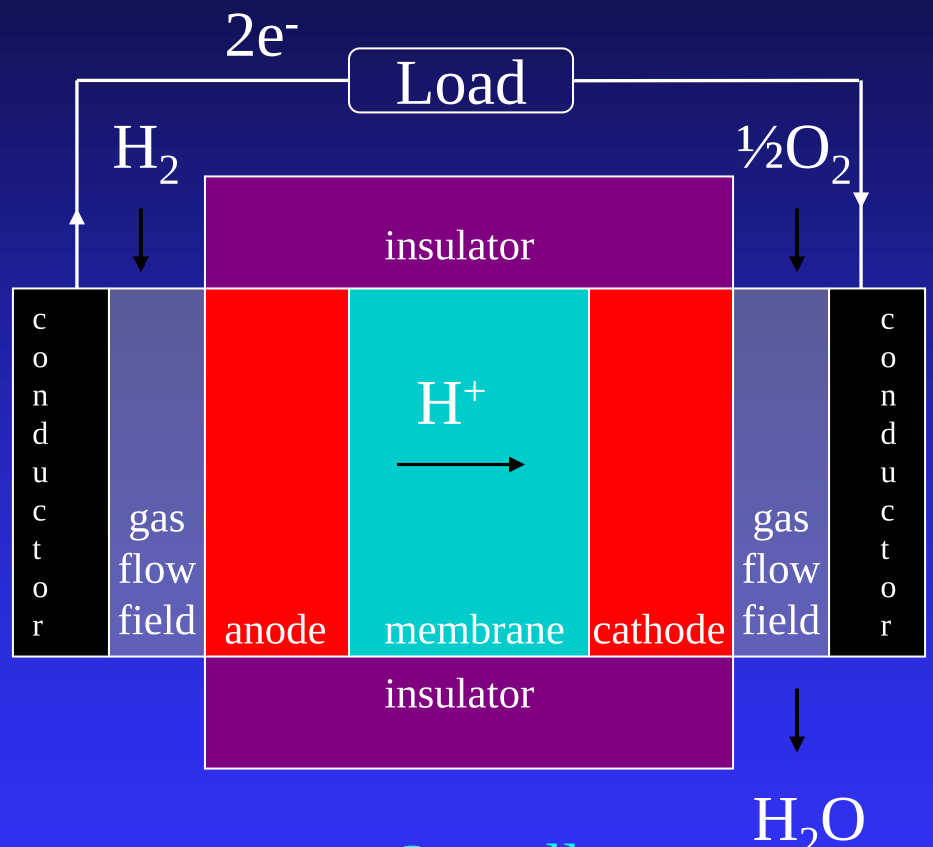
Uses of H_2

- Major Chemical Feedstock,. NH_3, MeOH, hydrogenated oils, Metals reduction
- H_2 engines, low but not zero emissions
- H_2 fired power generation
- H_2 co-fed with natural gas to microturbine or modified combustion engine

Fuel Cells

- Converts fuel (H_2) and oxidant (air) into electric power and heat continuously
- More efficient than a conventional heat combustion engine
- Only emission is H_2O for low temperature FC, and CO_2 for high temperature fuel cell at point of use.

PEMFC Schematic



Anode

$$H_2 \rightarrow 2H^+ + 2e^-$$

Cathode

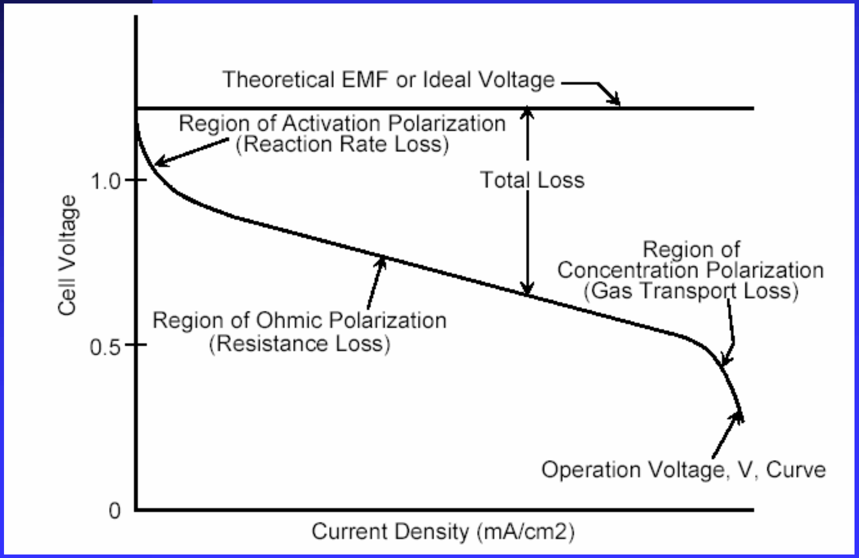
$$½O_2 + 2H^+ + 2e^- \rightarrow H_2O$$

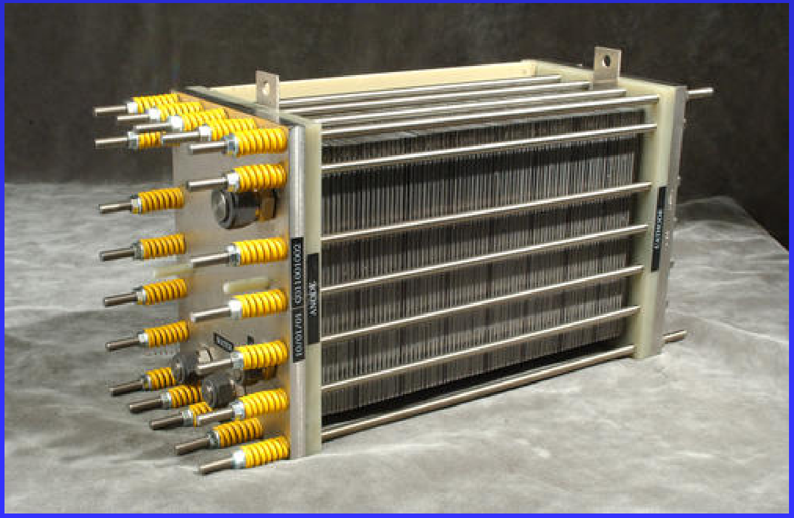
Overall

$$H_2 + ½O_2 \rightarrow H_2O$$

Fuel Cell Stack

- A single cell will operate at 0.6 V, so a stack of cells in series is needed for useful current
- Additional components such as bipolar plates or interconnects and seals are needed





Phosphoric Acid Fuel Cells

Barrow USPS Alaska

- Mature Technology at 250 kW
- Electrical efficiency 85%
- Operating temperature 165ºC – tolerates 1-2 % CO
- Low power density 250 mA cm^{-2} – large footprint
- Phosphoric acid leaches, deactivates Pt catalyst, Pt catalyst sinters – Requires refurbishment every 40, 000 h
- Carbon catalyst support combusts on fuel outage – requires N_2 for start up/shut down

Solid Oxide Fuel Cell

- Technology in Development <5 kW – <1 MW
- Electrical efficiency 50%
- Operating temperature 1000 ºC – CO is a fuel
- Ceramic construction of MEA – anode supported for structural stability
- High Temperature – component thermal expansion mismatch, long start up time, 8 h
- Fuel versatile – low cost catalysts to avoid coking or internal steam reforming

Proton Exchange Membrane Fuel Cell

Long Island Power Authority, NY

- Mature Technology for NASA in development for terrestrial applications
- Electrical efficiency >85%
- High power density >1 A cm^{-2} – large range of applications
- Operating temperature limited to 80 ºC – current membranes must be hydrated
- Expensive Pt catalyst– poor CO tolerance, Pt leaching when cycled
- Polymer membrane – susceptible to degradation, leading to corrosion of metal bipolar plate

PEM Fuel Cell Research

- Raise temperature of operation to 120-200 °C
  - Allows use of existing heat exchange hardware in vehicles and production of useful steam for stationary CHP .
- Improved electro-catalysts
  - CO tolerant anode
  - Improved kinetic of oxygen reduction at cathode – less Pt and OH radical.

H_2 from Biomass, areas of concern

- Anode tolerance to small reactive molecules
- Ammonia poisoning of electrolyte
- Silica deposition

Fuel Cell Cost Targets

- Automotive, pure H_2

	2003	2005	2010
Cost $/kW	200 - 2000	125	45
Durability, h	1000	2000	5000
T of operation, °C	80	120	120

- Stationary, including fuel processor

	2003	2005	2010
Cost $/kW	3000	1500	1000
Durability, h	>6,000	30,000	40,000
T of operation, °C	160	120-160	120-180

Partners

- Leadville Institute of Science and Technology
- Colorado School of Mines
- National Renewable Energy Laboratory
- Bio Energy Corporation
- Community Power Corporation
- Colorado Governors Office of Energy Management and Conservation